Imaging Module for Optical Reader

Field of the Invention

The present invention relates to optical reading devices in general and in particular to an apparatus for packaging illumination optical elements, receive optical elements, and signal processing elements of an optical reader.

Background of the Invention

Currently available optical readers include illumination elements, electronic signal processing, image capture and decoding circuitry that are carried by more than one circuit board. For, example, shown in U.S. Pat. No. 5,780,834 is an optical reader having numerous circuit boards, including an a LED board for carrying illumination LEDs, an "imaging board" carrying an image sensor and circuitry for processing signals generated from the image sensor, and a "mother board" carrying image capture and decoding circuitry.

Assembly of the multiple circuit board arrangement of the prior art is time consuming and expensive. Assembly of a prior art reader requires mounting of separate circuit boards to separate internal structures of a reader, and providing electrical connection between the multiple circuit boards. In addition adding to being difficult to assemble, the multiple circuit board design imposes size requirements on the optical reader housing in which the electrical components are to be integrated.

There is a need for an improved packaging method and apparatus for packaging optical and electrical components of an optical reader.

Summary of the Invention

According to its major aspects and broadly stated the present invention is a module for packaging optical illumination, optical receive, and electrical signal processing components of an optical reader.

The module includes a frame which carries a printed circuit board, preferably a printed circuit board (PCB) and various optical components. In one embodiment, the frame includes a back plate having a retainer for receiving an optical lens barrel, and a recess for receiving and aligning an image sensor which is carried by the PCB. The frame may also include resilient fingers which enable the frame to receive certain optical components of the module in an adhesiveless snap-fitting arrangement.

According to a preferred assembly method for assembling the module, the PCB is first mounted onto the frame's back plate such that the image sensor of the PCB is received and aligned by the recess of the back plate. Next, illumination and aiming LED's are soldered to the PCB to mount the LED's. As a space conserving measure, the LED's may be mounted so that a portion of rear surfaces of the illumination LED's oppose a portion of the top surface of the image sensor when mounted.

After the LED's are mounted to the PCB, additional components are incorporated in the module. In a preferred embodiment, a lens barrel is incorporated in the retainer, then an aperture plate having domed apertures for shaping light rays emanating from the aiming LED's is placed over the LED's. Finally, a diffuser lens plate for diffusing light rays emanating from the illumination LED's is snap-fit into

the frame. By providing spacers between the aperture plate and the diffuser plate, both of the aperture plate and the diffuser plate are secured in a stationary position inside the module by snap fitting of the diffuser plate onto the frame without use of adhesives or any other mechanical securing apparatuses.

In addition to having diffusers for diffusing illumination light, the diffuser plate may also include lenses for focusing light generated by the aiming LED's. In one embodiment of the invention, the aiming LED's and their associated optics project a solitary horizontal aiming line onto a target in a field of view.

The printed circuit board may be a full function printed circuit board which carries a solid state image sensor and essentially the entirety of electronic circuitry required for supporting essentially all of the processing and control operations to be performed by the optical device in which the module is to be incorporated. Circuitry incorporated in the single PCB includes signal processing circuitry for processing signals generated from the image sensor, image capture circuitry for storing image data, and decoding and/or recognizing circuitry for decoding and/or recognizing indicia represented in image data that has been stored.

In order to accommodate the full function circuit board, the rear surface of the frame's back plate should be made to have a central recess for aligning and receiving the image sensor, and peripheral recesses for accommodating circuit elements such as electrical components and/or wiring which may emanate from the front surface of the full function printed circuit board.

The complementary components of the module are shaped so that the completed module exhibits a cubic rectangular form, thereby reducing the overall volume consumed by the entirety of optical components and at least the image sensing component of the reader in which the module is installed.

A major feature of the invention is the incorporation of essentially all of the illumination elements required of an optical reader, including illumination and aiming light sources, and an image sensor onto a single circuit board. This significantly simplifies assembly, reduces material consumption, and thereby reduces the overall cost of producing the module.

Another feature of the invention is the snap fitting arrangement between the plate components of the module and the frame. The snap fitting arrangement for mounting several components of the frame eliminates the need for adhesives or other mechanical mounting agents, simplifies assembly, and thereby further reduces costs.

Another feature of the invention is the positioning of the LED's to partially oppose the image sensor when mounted. This feature reduces the required overall size of the module, thereby allowing incorporation of the module into smaller readers and further reducing costs.

Still another feature of the invention, in one embodiment, is the incorporation of essentially the entirety of electronic circuitry components required for essentially all of the signal processing and control operations required of the optical reader in which the module is to be incorporated in a single PCB. This feature enables essentially all of the electrical component required of an

optical device in which the module is to be incorporated to be installed simply by installing the module in the device.

Another feature of the invention is the projection of a solitary horizontal aiming line by the module's aiming LED's and their associated optics. The projection of a solitary horizontal aiming line for aiming reduces the space requirements of the aiming optics and reduces costs.

Yet another feature of the invention is the packaging of the entirety of the optical elements and at least the image sensor of the electrical components of an optical reader into a packaged module having a rectangular cube configuration. The rectangular cube configuration is stackable and highly space efficient and as such, enables simplified transport of the module and installation of reader optical and electrical components into reader housings of smaller size than was previously possible.

In addition to minimizing the size of the module, the module's configuration provides protection for internal components. The module's closed wall configuration provides a containment for internal components of the module, and substantially prevents outside objects from coming in contact with sensitive internal components of the module such as the module's image sensor and LED's.

These and other details, advantages and benefits of the present invention will become apparent from the detailed description of the preferred embodiment herein below.

Brief Description of the Drawing

For a fuller understanding of the nature and objects of the invention, reference should be made to the following

detailed description of a preferred mode of practicing the invention, read in connection with the accompanying drawings, in which:

Fig. 1A is a front perspective assembly diagram illustrating assembly of an image capture module according to the invention;

Fig. 1B is a rear perspective assembly diagram illustrating assembly of an image capture module according to the invention;

Fig 1C is a front perspective view of an assembled image capture module according to the invention;

Fig. 1D is a rear perspective view of an assembled image capture module according to the invention;

Fig. 1E is a representation of a preferred illumination and ***aiming*** pattern projected by a module in accordance with the invention;

Fig. 1F is a block diagram for illustration of functional and control features of the invention;

Fig. 2A - 2E are perspective views of various optical reader housings in which the invention may be incorporated;

Fig. 3 is a side view of a prior art reader illustrating a prior art multiple circuit board arrangement.

Detailed Description of the Invention

An embodiment of an imaging module 10 according to the invention is shown in Figs. 1A through 1D. Imaging module 10 is specifically designed for use in an indicia reader such as a bar code reader, an optical character recognition (OCR)reader or in a reader having both bar code and OCR reading capabilities. However, it will be understood that

features of module 10 may also find use in other devices requiring image capture including video cameras, digital cameras, and medical viewing instruments.

Module 10 includes mounting frame 12 which is adapted to receive both electrical components and optical components of an imaging system. Specifically, mounting frame 12 receives a circuit board, shown as being provided by a printed circuit board (PCB) 14, illumination LED's 16, aiming LED's 18, an aiming LED ~~lens~~ aperture plate 24 and diffuser plate 26. LED's 16, 18 could be substituted for by such light sources as laser diodes, filament based lamps, other solid state light sources, and fiber optic illumination devices.

Referring now to specific attributes of frame 12, frame 12 includes a back plate 30 and sidewalls including top sidewalls 31 and side sidewalls 31'. Back plate 30 includes a recess 34 for receiving a solid state image sensor chip 32 and, in one embodiment, a plurality of pin holes 36 for receiving leads 38 of illumination and/or aiming light sources, normally provided by LED's 16, 18. Back plate 30 may further include a retainer 40 for receiving a receive optics lens assembly 41 shown as being provided by a lens barrel, which may be installed in retainer 40 prior to or after any step in the assembly process which will be described herein below.

In assembling module 10, an assembler may first mount PCB 14 to back plate 30 with use of screws 56 or adhesives and then orients frame 12 so that opening 13 is exposed. When PCB 14 is mounted to back plate 30, image sensor 32 carried by PCB 14, is received and aligned by center recess 34 which is shaped complementarily with the shape of image sensor 32 as

shown. After mounting PCB 14 to frame 12, an assembler mounts illumination LED's 16 and aiming LED's 18 to PCB 14.

To mount LED's 16, 18 to PCB 14, an assembler pushes leads 38 of LED's 16, 18 through aligned pin holes 36 and 54 of back plate 30 and PCB 14, then solders the LED's 16, 18 to PCB 14. Preferably, an assembler first positions all of the LED's 16, 18 in their respective pin holes before soldering any of them. In soldering LED's 16, 18 rear surface 15 of PCB 14 should face in an orientation where it is easily accessed by an assembler. To the end that LED's 16, 18 remain in their desired orientation substantially normal to PCB 14 during soldering, a fixture (not shown) shaped to receive LED's 16, 18, of the type well known to persons skilled in the optical module assembly art can be temporarily applied over LED's 16, 18 through the soldering process.

While back plate 30 of frame 12 is shown as having pin holes 36 it will be understood that the entire region of back plate 30 containing pin holes 36 and recess 34 could be eliminated leaving back plate 30 to consist essentially only of receive optical lens assembly retainer 40. In such an embodiment, a substantial portion of the front surface 15 of PCB 14 would be exposed to an assembler upon mounting of PCB 14 to frame 12. In the case that back plate 30 does not contain material defining pin holes 36, LED's 16, 18 may be front mounted to front surface 15 of a PCB which in such an embodiment would not require pin holes for receiving LED leads 38.

An important feature of the invention is that leads 38 of illumination LED's 16 are installed in a nearly abutting relation to sides 33 of image sensor 32 so that a portion of

rear surfaces 19 of LED's 16 oppose a portion of a front surface 33 of image sensor 32 when the LED's 16 are completely installed. This arrangement reduces the size of module 12, enabling it to be installed in smaller sized optical readers.

After LED's 16, 18 are mounted onto PCB 14, an assembler installs aperture plate 24 in frame 12 so that domes 42 of aperture plate 24 fit over aiming LED's 18. Domes 42 of aperture plate should be opaque to substantially block all light emanating from aiming LED's 18 except for light which exits domes 42 through slit apertures 43. Slit apertures 43 should be formed so that a desired shaped aiming pattern of illumination is projected onto a target, T. Preferably, aperture slits 43 are shaped rectangularly so that a horizontal line pattern is projected onto a target.

Referring to further aspects of aperture plate 24, aperture plate 24 includes cutaway sections 46 which provide clearance to allow plate 24 to be fit over illumination LED's 16. The sidewalls of domes 42 and of cutaway sections 46 may or may not contact the LED's they fit over. However, it is not necessary that the sidewalls of either domes 42 or cutaway sections 46 have any influence on the alignment or LED's 16, 18 since LED's 16, 18 are aligned in their desired orientation substantially normal to the surface 33 of image sensor 32 and PCB 14 by virtue of the fact that they are held in a desired orientation while being soldered and, in the embodiment shown, by virtue fact that the flat surfaces of LED bases 17 are biased against the flat surface of back plate 30 during the assembly process.

After aperture plate 24 is placed over LED's 16,18 and moved toward back plate 30, diffuser plate 26 is snap fit into

frame opening 13 of frame 12. Diffuser plate 26 includes diffusers 27 for diffusing light emanating from illumination LED's so that a target area, T, is substantially homogenously illuminated by light emanating from illumination LED's 16. Resilient fingers 48 having hook ends 49 may be formed in top 31 or side 31 sidewalls of frame 12 to enable snap fitting of plate 26 onto frame 12. In the embodiment shown, an assembler snap fits plate 26 onto frame 12 by pulling back resilient fingers 48 and pushing plate 26 toward back plate 30 then releasing fingers 48 to lock plate 26 into a position inside module 10. Spacers 52 of aperture plate 24 (which in the alternative may be formed on plate 26) operate to bias aperture plate 24 toward back plate 30 when diffuser plate 26 is snap fit onto frame 12. When plate 26 is snap fit into frame 12, spacers 52 transfer the force imparted by fingers 48 on plate 26 to plate 24 to the end that both aperture plate 24 and diffuser plate 26 are firmly secured inside frame 12 without use of adhesives or outside mechanical securing apparatuses or agents such as screws or pins.

In addition to having diffusers 27 for diffusing light emanating from illumination LED's 16, diffuser plate 26 may also include lenses 25 for focusing light emanating from aiming LED's 18 as shaped by aperture slits 43 so that a focused narrow line is projected onto a target area T. A representation of a preferred illumination pattern projected by the illumination system of module 10 is shown in Fig. 1E. In Fig. IE, area 72 represents the region of a target area T illuminated by illumination LED's 16 while area 74 represents the region of the target area highlighted by aiming LED's 18 and their associated optics. It is seen that aiming LED's 18

and their associated optics preferably project a solitary horizontal line 74 onto a target area which is in contrast with the complex geometry aiming patterns of prior art 2D optical readers. The selection of a solitary horizontal aiming pattern reduces the size of module 10, as it eliminates the need to provide more than 2 light sources and/or optics for reflecting light generated from the aiming pattern light source or sources.

An important feature of the invention is that essentially all the illumination elements of a reader in which module 10 is to be incorporated are included on a single circuit board shown as being provided by PCB 14. This is in contrast to the design of the prior art reader shown in Fig. 3 in which illumination elements and image sensing elements are spread out over several circuit boards. In the prior art device shown in Fig. 3, an aiming illumination source 53 is mounted to a first circuit board 54, illumination LED's are mounted to a second circuit board 56, while image sensor 32 is mounted to a third circuit board 58. The assembly of a module of this prior art design is difficult and requires material components not required by the design of the present invention including circuit boards 54, 56 and electrical connectors between the circuit boards such as connector 57. Providing a single circuit board that carries an image sensor, illumination LED's, and aiming LED's significantly simplifies assembly, reduces material consumption and thereby reduces the overall cost of producing the module.

Another important aspect of the invention, in one embodiment, is that essentially all electronic circuitry supporting the data processing operations required of module

10 are located on single, full function PCB 14, including circuitry for processing signals generated from image sensor 32, circuitry for capturing image data into a memory device, circuitry for decoding and/or recognizing indicia represented in captured image data. Circuitry for supporting serial transfers of data to peripheral devices may also be carried by PCB 14.

The all in one PCB arrangement of the present invention is in contrast to the traditional design in the prior art wherein circuitry for processing signals from an image sensor, circuitry for capturing and decoding image data and circuitry supporting serial interfacing with external devices are spread out over more than one circuit board.

In the design of the prior art reader shown in Fig. 3, a first vertically oriented circuit board 56 is provided for carrying circuitry for processing signals generated by an image sensor 32 and a second horizontally oriented circuit board 60, known as a "mother board" is provided for carrying circuitry for storing image data and for decoding symbologies.

The one PCB design of the present invention provides numerous advantages over the two PCB design of the prior art. The multiple circuit board arrangement of the prior art requires a complex assembly procedure wherein the first circuit board 58 is mounted to a first internal structure of the reader in which it is incorporated, the second circuit board is mounted to a second internal structure of the reader, and then the two circuit board are electrically connected. The separate horizontal and vertical orientations of the two circuit boards 58, 60 is inefficient in terms of space

consumption and imposes restrictions on the configurations of housings in which the reader optical and electrical components may be incorporated. The one full function PCB design of the present invention does not exhibit these disadvantages.

To the end that essentially the entirety of the required electronic circuitry of an optical reader can be packaged into a single printed circuit board, the back surface of the frame's back plate 30 should be configured to accommodate electrical components that will extend forward from the front surface 15 of PCB 14. Accordingly it is seen that the rear surface of back plate 30 includes a central recess 34 for aligning and receiving solid state image sensor 32 and peripheral recesses 35 for accommodating electrical circuitry such as components and/or conductors which may protrude from the front surface of PCB 14.

In addition to the features that have been described herein above, it will be seen that additional benefits are yielded by features relating to the overall shape and configuration of module 10. As best seen in Figs. 1C and 1D, sidewalls 31 and 31' of frame 10, together with PCB 14 and plate 26 define a module having a substantially cubic rectangular overall form. The cubic rectangular form is highly space efficient relative to the form of optical reader imaging modules in the prior art. With reference again to Fig. 3 it is seen that the form of prior art imaging module 52 is highly irregular in that it contains members such as member 53 and member 56 that protrude extraneously from the major body of module 52. The volume conserving cubic rectangular configuration of the module of the present invention facilities incorporation of the module into optical reader

housings of smaller interior volume than was possible with the irregular imaging module designs of the prior art.

The volume conserving cubic rectangular form of module, in addition to facilitating incorporation of the module into a smaller volume optical reader housings, renders the module easier to package. This is because the cubic rectangular form allows several modules to be stacked neatly on top of one another allowing more modules to be packaged in a certain sized container than was possible with modules of previous designs. The stackability of the modules also allows the modules to be packaged more securely without outside securing agents such as bubble paper and/or foam particles, since several modules can be packed in such a way that several modules impart stabilizing tensioning forces on one another. Packaging of several modules in a box or container containing several modules is an important consideration in the case that several modules 10 are to be transported from a first location where they are assembled to a second location where they are to be incorporated into several optical reader housings.

Another feature relating to the outer configuration of module 10, is that the defined outer walls of module 10 serve as a containment for protecting and preventing damage to relatively fragile and sensitive internal components of the module. In the prior art, with reference again to Fig. 3, it is seen that sensitive and fragile and sensitive components of module such as light source 53 and LED circuit board 56 extend extraneously from the major body of the module and as such, are susceptible to being brought in contact with external objects especially during transport and during installation of the module into a reader housing. In the embodiment shown in

Figs. 1A - 1D, substantially all fragile sensitive components, including all light sources of module 10, and image sensor 32, are disposed inside a substantially rigid containment structure defined by sidewalls 31, 31' and PCB 12 and the combination of sidewalls 31, 31' and diffuser plate 26.

The substantially rigid containment of sensitive internal components of the module provided by the combination of sidewalls 31, 31' and PCB 14 and/or the combination of sidewalls 31, 31' and diffuser plate 26 eliminate the need to package the module with shock absorbing material such as bubble paper or foam particles during transport and allows the module to be safely transported from one location to another without substantial risk of damage to sensitive internal components.

Methods for making, and possible material compositions for various components of imaging modules are discussed in commonly assigned U.S. Serial No. 09/312,479 incorporated herein by reference.

A block diagram illustrating one type of optical reading device in which the invention may be incorporated is described with reference to Fig. 1F.

Optical reader 110 includes an illumination assembly 120 for illuminating a target object T, such as a 1D or 2D bar code symbol, and an imaging assembly 130 for receiving an image of object T and generating an electrical output signal indicative of the data optically encoded therein. Illumination assembly 120 may, for example, include an illumination source assembly 122, such as one or more LEDs, together with an illuminating optics assembly 124, such as one or more reflectors, for directing light from light source 122 in the

direction of target object T in module 10. The illumination assembly in the embodiment of Figs. 1A - 1D is provided entirely by LEDs 16. Illumination assembly 120 may be eliminated if ambient light levels are certain to be high enough to allow high quality images of object T to be taken. Imaging assembly 130 may include an image sensor 132, such as a 1D or 2D CCD, CMOS, NMOS, PMOS, CID OR CMD solid state image sensor, together with an imaging optics assembly 134 for receiving and focusing an image of object T onto image sensor 132. The array-based imaging assembly shown in Fig. 1F may be replaced by a laser array based imaging assembly comprising multiple laser sources, a scanning mechanism, emit and receive optics, at least one photodetector and accompanying signal processing circuitry.

Optical reader 110 of Fig. 1F also includes programmable control unit 140 which preferably comprises an integrated circuit microprocessor 142 and an application specific integrated circuit (ASIC 144). The function of ASIC 144 could also be provided by field programable gate array (FPGA). Processor 142 and ASIC 144 are both programmable control devices which are able to receive, output and process data in accordance with a stored program stored in memory unit 145 which may comprise such memory elements as a read/write random access memory or RAM 146 and an erasable read only memory or EROM 147. RAM 146 typically includes at least one volatile memory device but may include one or more long term non-volatile memory devices. Processor 142 and ASIC 144 are also both connected to a common bus 148 through which program data and working data, including address data, may be received and transmitted in either direction to any circuitry that is also

connected thereto. Processor 142 and ASIC 144 differ from one another, however, in how they are made and how they are used.

More particularly, processor 142 is preferably a general purpose, off-the-shelf VLSI integrated circuit microprocessor which has overall control of the circuitry of Fig. 2, but which devotes most of its time to decoding image data stored in RAM 146 in accordance with program data stored in EROM 147. Processor 144, on the other hand, is preferably a special purpose VLSI integrated circuit, such as a programmable logic or gate array, which is programmed to devote its time to functions other than decoding image data, and thereby relieve processor 142 from the burden of performing these functions.

The actual division of labor between processors 142 and 144 will naturally depend on the type of off-the-shelf microprocessors that are available, the type of image sensor which is used, the rate at which image data is output by imaging assembly 130, etc. There is nothing in principle, however, that requires that any particular division of labor be made between processors 142 and 144, or even that such a division be made at all. This is because special purpose processor 144 may be eliminated entirely if general purpose processor 142 is fast enough and powerful enough to perform all of the functions contemplated by the present invention. It will, therefore, be understood that neither the number of processors used, nor the division of labor therebetween, is of any fundamental significance for purposes of the present invention.

With processor architectures of the type shown in Fig. 1F, a typical division of labor between processors 142 and 144 will be as follows. Processor 142 is preferably devoted

primarily to such tasks as decoding image data, once such data has been stored in RAM 146, recognizing characters represented in stored image data according to an optical character recognition (OCR) scheme, handling menuing options and reprogramming functions, processing commands and data received from control/data input unit 139 which may comprise such elements as trigger 174 and keyboard 178 and providing overall system level coordination. Processor 144 is preferably devoted primarily to controlling the image acquisition process, the A/D conversion process and the storage of image data, including the ability to access memories 146 and 147 via a DMA channel. Processor 144 may also perform many timing and communication operations. Processor 144 may, for example, control the illumination of LEDs 122, the timing of image sensor 132 and an analog-to-digital (A/D) converter 136, the transmission and reception of data to and from a processor external to reader 110, through an RS-232, a network such as an ethernet, or a serial bus such as USB, (or other) compatible I/O interface 137 and the outputting of user perceptible data via an output device 138, such as a beeper, a good read LED and/or a display monitor which may be provided by a liquid crystal display such as display 182. Control of output, display and I/O functions may also be shared between processors 142 and 144, as suggested by bus driver I/O and output/display devices 137′ and 138′ or may be duplicated, as suggested by microprocessor serial I/O ports 142A and 142B and I/O and display devices 137" and 138′. As explained earlier, the specifics of this division of labor is of no significance to the present invention.

In accordance with a feature of one embodiment of the

invention described with reference to Figs. 1A-1D, essentially all of the electrical signal processing components described with reference to Fig. 1F may be carried by a single circuit board, PCB 14, as is indicated by dashed-in border 14, of Fig. 1F. In order to incorporate essentially all of the electrical signal processing components of Fig. 1E onto a single PCB 14, it is normally necessary to integrate several electrical components into a reduced number of electrical components. For example, using known integrated circuit fabrication techniques, components 142, 144, 146, and 147 and interfaces 137, 137', and 137" can be incorporated in a single integrated circuit chip of reduced size. Further, as explained in an article by Eric R. Fossum entitled *Digital Camera System on a Chip*, IEEE Computer Society (IEEE Micro), Volume 18, Number 3, May/June 1998, image sensor 132, signal processing components 135, 136, and components 142, 144, 146, 147, 137, 137', and 137" may be incorporated in a single integrated circuit of reduced size.

Figs. 2A through 2H show examples of types of housings in which the present invention may be incorporated. Figs 2A and 2B show a 1D optical reader 110-1, while Figs 2C-2H show 2D optical readers 110-2, 110-3, 110-4. Housing 112 of each of the optical readers 110-1 through 110-4 has incorporated therein is adapted to be graspable by a human hand and at least one trigger switch 174 for activating image capture and decoding and/or image capture and character recognition operations. Readers 110-1, 110-2, 110-3 include hard-wired communication links 178 for communication with external devices such as other data collection devices or a host processor, while reader 110-4 includes an antenna 180 for

providing wireless communication with an external device such as another data collection device or a host processor.

In addition to the above elements, readers 110-3 and 110-4 each include a display 182 for displaying information to a user and a keyboard 184 for enabling a user to input commands and data into the reader.

Any one of the readers described with reference to Figs. 2A through 2H may be mounted in a stationary position as is illustrated in Fig. 2I showing a generic optical reader 110 docked in a scan stand 190. Scan stand 190 adapts portable optical reader 110 for presentation mode scanning. In a presentation mode, reader 110 is held in a stationary position and an indica bearing article is moved across the field of view of reader 110.

While this invention has been described in detail with reference to a preferred embodiment, it should be appreciated that the present invention is not limited to that precise embodiment. Rather, in view of the present disclosure which describes the best mode for practicing the invention, many modifications and variations would present themselves to those skilled in the art without departing from the scope and spirit of this invention, as defined in the following claims.